Climate Change and Drought Impacts on Agriculture in Mehsana District: A Geoinformatics Approach

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ABSTRACT

Drought is one of the most dangerous natural hazards that affects people's socio-economic activities to large scale. Drought may last for Years or months, or may be declared after as few as 15 days. As per report, Gujarat faces the drought generally once in three years. The study was taken up for the monitoring Impact of climate change and drought on agriculture using geoinformatics techniques in Mehsana district in Gujarat State. Earth observation data (LANDSAT 7 & 8 ETM+), Standardized Precipitation Index, Normalized Differential Vegetation Index and Aridity index were used to analyse drought severity. Daily rainfall data over the study area were obtained from Water Resources Department, Government of Gujarat for the period of study (2002-2017). Land use mapping has been done using Landsat 7 and 8 data of the year 2002, 2017 and 2018. The area of interest is Mehsana district which has been clipped from downloaded Landsat images using district boundary. The SPI was generated using seasonal rainfall data of four stations named Ambaliyasan, Ransipur, Red Laxmi and Thol. The data was from June to September for study period (2002-2017). The results suggest that the Mehsana District had felt severe drought in 2002 A.D. It can be also concluded that since 2012 Mehsana district has not felt any major drought.

***Keywords**: Drought, Standard Precipitation Index (SPI), Aridity Index, Normalized Differential Vegetation Index (NDVI), Rainfall, Rainfall variability, Remote sensing*.

Objectives

- To study the impact of drought on agriculture in Mehsana district using multi-date Landsat satellite data
- To analyse the meteorological data and compute meteorological indices related to drought and study its variability over the period of 15 years.
- Relate the meteorological indices with agriculture drought condition in Mehsana district.

I. INTRODUCTION

Drought:

Drought can be understood as very low rainfall or no rainfall over a period of time. At the time of drought, soil moisture decreases and even hydrological cycle imbalances. The outcome of drought is water and food shortage which causes long term effect on economic, environmental and health impacts on population. The major cause of drought is shortage of rainfall or snow over a period of time. The wind pattern changes due to weather and water cycle changes that moves clouds and moisture through the atmosphere can cause a place to not receive its normal amount of snow or rain over a long period of time. In a place where most of the people uses water come from a river, a drought in that area can be caused by places upstream, not receiving enough moisture. There would be less water in the river for those people who are live along the river to use. Humans can also play a big role in drought. If people use too much water during times of normal rainfall, we might not have enough water when a drought happens.[16] Drought on different basis is generally classified into Four categories.

1. Meteorological Drought
2. Agricultural Drought
3. Hydrological Drought
4. Socioeconomic Drought

Meteorological Drought:

Meteorological drought can be defined on the basis of the dryness (in comparison to some "normal" or average amount) and the duration of dry period. The deficiencies of precipitation in atmosphere precipitation are highly variable from region to region. So, the definitions of meteorological drought should be region specific.

We can take few examples like; few definitions of meteorological drought show periods of drought on the basis of the number of days with precipitation less than some specified threshold. But this identification is region specific which is characterized by a yearly precipitation regime such as a tropical rainforest, humid subtropical climate, or humid mid-latitude climate. Other definitions may relate actual precipitation departures to average amounts on annual, seasonal or monthly time scales. This meteorological drought mainly indicates deficit rain of different quantum.

1. Slight drought: When rainfall is 11 to 25% less from the normal rainfall
2. Moderate drought: When rainfall is 26 to 50% less than the normal rainfall.
3. Severe drought: When rainfall is more than 50% less than the normal rainfall

Agricultural drought:

Agricultural drought has various characteristics of meteorological (or hydrological) drought to agricultural impacts. Agriculture impacts includes differences between actual and potential evapotranspiration, focusing on precipitation shortages, soil water deficits, reduced groundwater or reservoir levels, and so forth. Plant water demand depends on superior weather conditions, its stage of growth, biological characteristics of the specific plant and the physical and biological properties of the soil. Definition of agricultural drought should be able to account for the variable susceptibility of crops during different stages of crop development, from emergence to maturity. If the moisture in topsoil is very low at planting time, it may inhibit germination, leading to low plant populations per hectare and a reduction of final yield. However, at initial seed growing phase, if moisture is sufficient in top soil but deficient in subsoil and can be filled as the growing season progresses or if rainfall meets plant water needs; the final yield may not be affected.[13]

Hydrological drought:

Hydrological drought is related with the periods of precipitation (including snowfall) shortfalls on surface or subsurface water supply (i.e., streamflow, reservoir and lake levels, groundwater). Watershed and river basin scale defines the frequency and severity of hydrological drought though all the droughts originate with a deficiency of precipitation, hydrologists are more concerned with how this deficiency plays out through the hydrologic system. These droughts are usually out of phase with the occurrence of meteorological and agricultural droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system such as streamflow, soil moisture, and groundwater and reservoir levels. As a result, these impacts are out of phase with impacts in other economic sectors. As an example, a precipitation deficiency may result in a rapid depletion of soil moisture that is almost immediately noticeable to agriculturalists, but the impact of this deficiency on reservoir levels may not affect hydroelectrical power production or recreational uses for many months. Also, water in hydrological storage systems like reservoirs, rivers etc. is often used for multiple and competing purposes including flood control,recreation, irrigation, navigation, hydropower, wildlife habitat and many which further complicating the sequence and quantification of impacts.[13]

Socioeconomic Drought:

Socioeconomic drought mainly related with supply and demand of goods including elements of hydrological, meteorological and agricultural drought. Due to its occurrence depends on the time and space, process of supply and demand to identify or classify droughts, this drought differs from above other droughts. Weather dependent goods supplies are food grains, forage, water, fish and hydraulic power. Water supply is sufficient for some years but it will be unable to meet human requirements after some years because of the natural variability of nature. This socioeconomic drought occurs when demand of goods is more than supply mainly due to increasing population and per capita consumption. Supply can be increased by improving production efficiency, technology or the construction or reservoirs, it may increase surface water storage capacity.[13]

Climate change and its impact on agriculture

Climate change is related changes in oceans, change in the pattern of weather, land surfaces and ice sheets, occurring over time scales of decades or longer. It can cause by many reasons like Earth's distance from the sun. Distance far from sun can send less energy and vice versa. volcano eruption can change climate for short time. Peoples can also play role in changing climate, as example driving car erupts greenhouse gases; burning coal, oil and gas which causes the air to heat up.[17]

Agriculture and climate change are interconnecting process, they both take place at global scale. Agriculture can be affected by many ways that includes increasing or decreasing temperature, ozone layer depletion, rainfall variation, heat waves, greenhouse gases increment, nutritional quality of some foods; and changes in sea level.[20]

II. STUDY AREA

Mehsana District is an administrative division of Gujarat, India, whose headquarters are at Mehsana. It was organized in 1902. It has an area of 5600 sq km², and a population of 2,27,727 out of which urban population is 514,330 while rural is 1,520,734(census 2011). The Nine Talukas are – Mehsana, Becharaji, Visanagar, Vijapur, Vadnagar, Kadi, Unja, Kheralu and Satalasana - and 600 villages. [21]

It is Located at North Latitude-23.02 and 24.09, East Longitude-71.21 and 75.52. Mehsana District is sharing border with Ahmedabad and Patan District to the South & West, Banaskantha District to the North, Sabarkantha and Gandhinagar Districts to the East. Mehsana District occupies an area of approximately 649 square kilometers. This District belongs to Western Indian.Connected to Ahmedabad by the Ahmedabad-Palanpur highway, and with Patan with the Mehsana-Patanhighway [21]

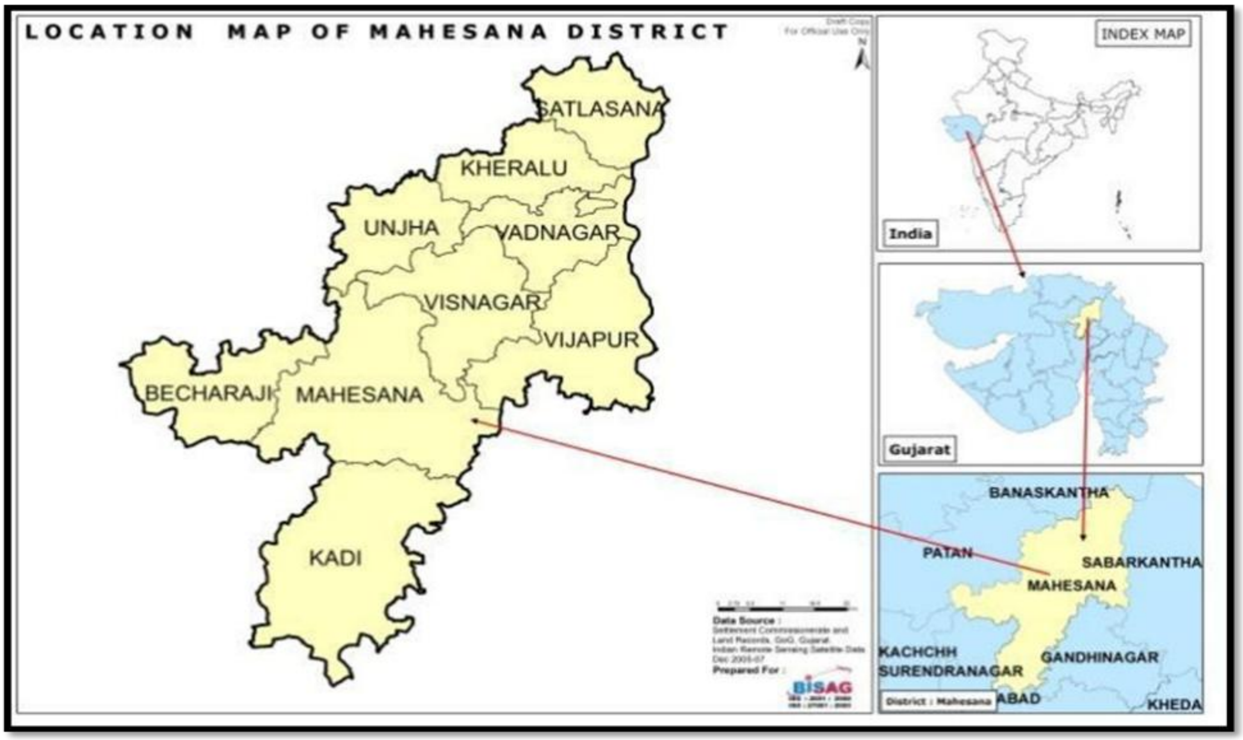

Figure 1: Mehsana district

IRRIGATION BY DIFFERENT SOURCES		
(Areas and numbers of structures)	NO.	Area Sq.km
Dug wells	8202	206
Tube wells/Borewells	11220	2289
Tanks/Ponds/Water conservation structures		18
Canals		206
Other Sources		9
Net Irrigated area (sq. km.)	2186	
Gross Irrigated area (sq. km.)	2733	
NUMBERS OF GROUND WATER MONITORING WELLS		
CGWB (As on 31-03-2012)	60	
No of Dug Wells	16	
No of Piezometers	44	
(All information is from 2014 district ground water brochure)		

Table 1: number of ground water irrigation sources [22]

Name of talukas	9 talukas named Becharaji,Kadi, Kheralu, Mehsana, Satlasna, Unjha, Vadnagar, Vijapur, Visnagar,
Population	20,27,727 (As per 2011 Census)
Total area	4484.10sq km
State highway	2
Railway	Available
Land type Geo structure	The land type is sandy and Goralu.
Temperature	Maximum- 46° Celsius and Minimum- 15° Celsius.
Border	The border area of district is 55 km and the pillar numbers are 976 to 986.
Rivers	Sabarmati, Rupen, Pushpavati, Saraswati, Khari
Rain	Average rainfall 827 mm (As per district groundwater brochure)

Table 2: Mehsana district facts

Demographics [21,22]**: -**

- MehsajiChavda, a Rajput and an heir of Chavda dynasty, established Mehsana.
- According to the 2011 census Mehsana district has a population of 2,027,727 roughly equal to the nation of Slovenia or the US state of New Mexico.
- Its population growth rate over the decade 2001-2011 was 9.91%.
- Mehsana has a sex ratio of 925 females for every 1000 males.
- Forest area is 72 sq.km, Net area shown is 3516 sq.km and Cultivable area is 4509 sq.km.
- Major crops of Mehsana are Wheat, Cotton, Castor Seeds, Brinjal, Potatoes, Tomatoes, Okra, Mango, Citrus, Sapota, Fennel seed, Psyllium and Cumin.
- In 2006-07, Mehsana produced 1.37 lakh Metric Tonnes (MT) of Fruits, 2.37 lakh MT of Vegetables and 4.65 lakh MT of Spices.
- Sardar Sarovar Project water for industrial supply is made available through its 6 branch canals.
- Eight talukas in the district are categorised as Over exploited and one as critical and as stage of development is 151.17% in the GWRE, 2004 report hence there is no further scope for development of the ground water resources.

III. MATERIALS AND METHODS

Data: -

Spatial Data:

1. Satellite Data of 2002 and 2018 (Landsat 7 and Landsat 8 OLI)

2. Vector data (Shape file, District boundary)

Non-Spatial Data:

1. Monthly Rainfall Data (2002-2017)
2. Monthly Temperature Data (2006-2017)

Software Used:

1. QGIS 2.8.9
2. ArcGIS 10.5
3. ENVI 5.3
4. MS office

Data Download

This process involves to find out area of interest and download raster and vector files accordingly. The area of interest is Mehsana district and to check the impact of drought on agriculture, we downloaded highest vegetation month which was in January month. Data was of 4th January 2002 and 9th January 2018 Landsat 7 and 8 data respectively.

Landsat has TM sensor and it is for raster images. This data was download from United States Geological Survey Earth explorer website. To extract the area of interest which is Mehsana district, we need to download Mehsana district boundary shapefile. diva-gis.org is the website from where shapefile was downloaded.

Pre-process

Pre-processing involves layer stacking tiles thus compile into one image and mosaicking compiled multi tiles. Layer stacking is a process for combining multiple images into a single image. In order to do that the images should have the same extent (number of rows and number of columns), which means you will need to resample other bands which have different spatial resolution to the target resolution. The software used for layer stacking was QGIS 2.8. In qgis this function in named as merge from raster tab.

From raster tab, Merge is the option by which we can layer stack and mosaic image. For mosaic we do not check layer stacking option.Mosaicking is third step which is required when the area of interest covers more than one path and row. Mosaicking is the step which combines two stacked images into one image without losing its quality. Mosaic function from ArcGIS is used for Landsat 8 image and seamless mosaicking function used in ENVI for Landsat 7 image.

Clipping

Clipping is the process for extracting area of interest from entire image. This clipping either can be raster-raster, vector-vector or raster-vector. In our case it is raster-vector. Now the downloaded shape file is coming into use.

First, extracting/clip Mehsana district area from India. Clip option is located in Qgis vector tab which clips shape file. Clipper option in raster tab extracts desired raster file in image

Classification for land use change analysis

The purpose of classification is to check land use. Land use classification is the systematic arrangement of various classes of land on the basis of certain similar characteristics, mainly to identify and understand their fundamental utilities, intelligently and effectively in satisfying the needs of human society (Mandal, 1969 and 1990). The best use of each parcel of land requires a scientific and methodologically appreciable classification. This may help us in investigating the land use problems and be the basis of planning for the best use of our land after considering the major land use categories.

Here I used maximum likelihood supervised classification in ArcGIS. In ArcMap, add image classification toolbar. Then create training samples for different classes. Save the signature file and perform Maxlikelihood classification. Further accuracy assessment and area calculation was done. First creation of random accuracy points and verify with ground truthing. This accuracy was measured by confusion matrix. Here I have done it on 2002 and 2018 images. The accuracy I got was 88% and 91% respectively.

NDVI

Normalized Difference Vegetation Index (NDVI) is a method to measure Vegetation by calculating difference between NIR (near-infrared which vegetation strongly reflects) and red visible band (which vegetation absorbs).

This NDVI ranges from -1.0 to +1.0 but there is no distinct boundary between classes. So, we applied NDVI thresholding to distinguish between different classes.

For example, when you have negative values, it's highly possibility that it's water. On the other hand, if you have a NDVI value close to +1, there's a high possibility that it's dense green leaves. But when NDVI is close to zero, there isn't green leaves and it could even be an urbanized area. As shown below, **Normalized Difference Vegetation Index (NDVI)** uses the NIR and red channels in its formula.

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

This index can be done in raster calculator. Extract NIR and Red band and write this formula in calculator. After getting a new image, thresholding is to be done for NDVI classified image by changing the symbology into classified and give number of desired classes.

Collection of Meteorological data

To check the impact of drought on agriculture, we need data of climate like rainfall data and temperature data. This data can also be used for aridity and standard precipitation indies. It requires data of 2002 and 2018 monthly rainfall data and Tmax and Tmin monthly temperature data. This data is available at state data collection centre and it can be obtained by filling up the official form.

Standard Precipitation Index (SPI):

Standard Precipitation Index is a state-of-the-art method developed for assessing climatic variability (McKee T. B., Doesken N. J., Kleist J.,1995; McKee T. B., Doesken N. J., Kleist J., 1993). Standardized Precipitation Index (SPI) is an index that was developed to quantify precipitation deficit at different time scales, and can also help assess drought severity (Das S, Choudhury MR, Nanda S., 2013). The result of that SPI allows to analyse the drought at given time scale of interest for any rainfall station with historic data. SPI is a number to each year precipitation which transformed into probability distribution. So, a normal distribution year has SPI value nearly zero. It was done in Microsoft Excel sheet.

SPI = {(Xij − Xim) /σ}

Where,

Xij= is the seasonal precipitation,

Xim= its long-term seasonal mean, and

σ=its standard deviation.

SPI is computed with the help of rainfall data of four stations. The value of SPI is between 2.0+ to -2 and less. Negative value after -1 shows dry season and values above 0 shows normal to extreme wet season. The result of Standard Precipitation Index south eastern and north-western part of the region has moderate climatic condition and few amounts of area come under extreme wet or good rainfall condition.

SPI Values	
2.0+	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near Normal
-1 to -1.49	Moderately dry
-1.5 to -2	Severely dry

-2 and less	Extremely dry

Aridity Index:
De Mortonne (1926) put forward the De Mortonne's index by modifying the Lang's rain factor in which he suggested to divide the annual precipitation in mm by the mean annual temperature in °C + 10. This index is one of the best known and widely used aridity/humidity indices in applied climatology (De Martonne 1925; Croitoru et al. 2012). For the arid/humid climate classification, this index is very important. Despite the fact that it is one of the oldest indices, it is still used with good results worldwide in order to identify dry/humid conditions of different region (Coscarelli et al. 2004; Baltas 2007; Shahid 2008, 2010; Zarghami et al. 2011; Adnan and Haider 2012). This index is given by equation:
$I = P/T + 10$
Where, I = Index of aridity, P = Annual Precipitation & T = Mean Annual Temperature.

Aridity value	**Climatic Condition**
$I<5$	Hyper arid
$5<I<10$	Semi-Arid
$10<I<20$	Arid
$20<I<24$	Normal
$24<I<28$	Sub Humid
$28<I<35$	Humid
$35<I<55$	Very humid
$55<I$	Extremely humid

IV. RESULT AND DISCUSSION

clipping area of interest:
The Landsat image is square 30*30-meter resolution image and area of interest is Mehsana district which is not covered in one image. So mosaicking and clipping area of interest only way to get desired image. To clip the area, we required Mehsana boundary district shape file. The figure 2 is clipped image which is in true colour composite.

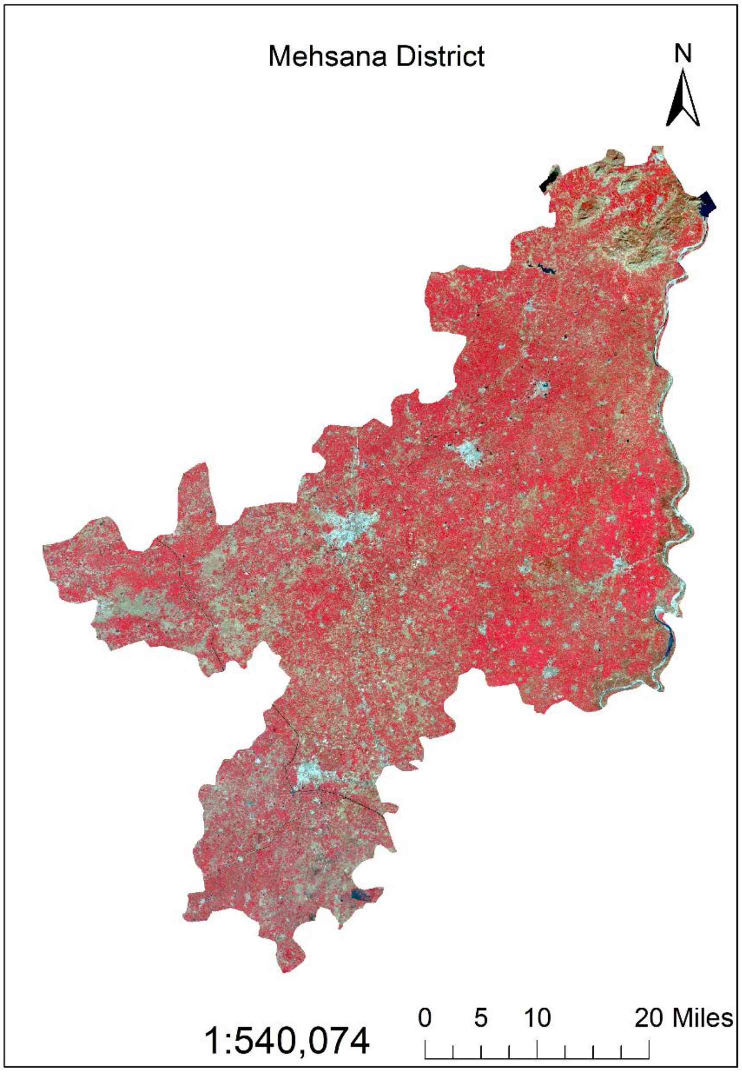

Figure2: clipped 2018 Mehsana district true colour image

NDVI Based Drought Condition Assessment

There are various vegetation indices but among them most widely used is Normalized differential vegetation index. This index is mainly used for drought assessment because of its easy calculation and easy interpretation.

It is clearly visible that vegetation in 2002 image was only at centre region of district and in 2018 it spread entire district. Here we can also see 2017 impact on 2018 because the Standard precipitation index and aridity index was available till 2017.

Figure 6 is zoomed NDVI classified image which shows all classes (water, urban, fellow land, barren land and vegetation) visible.

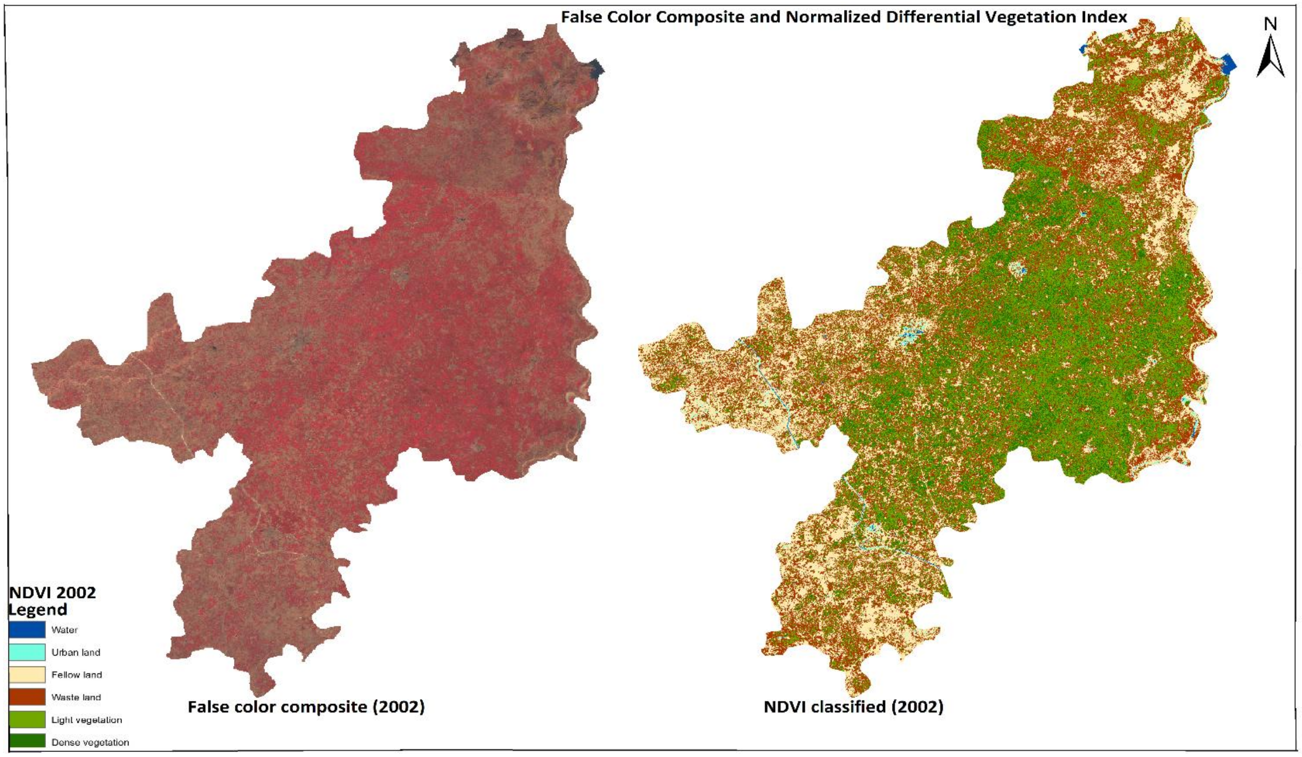

Figure 3: NDVI and FCC of year 2002

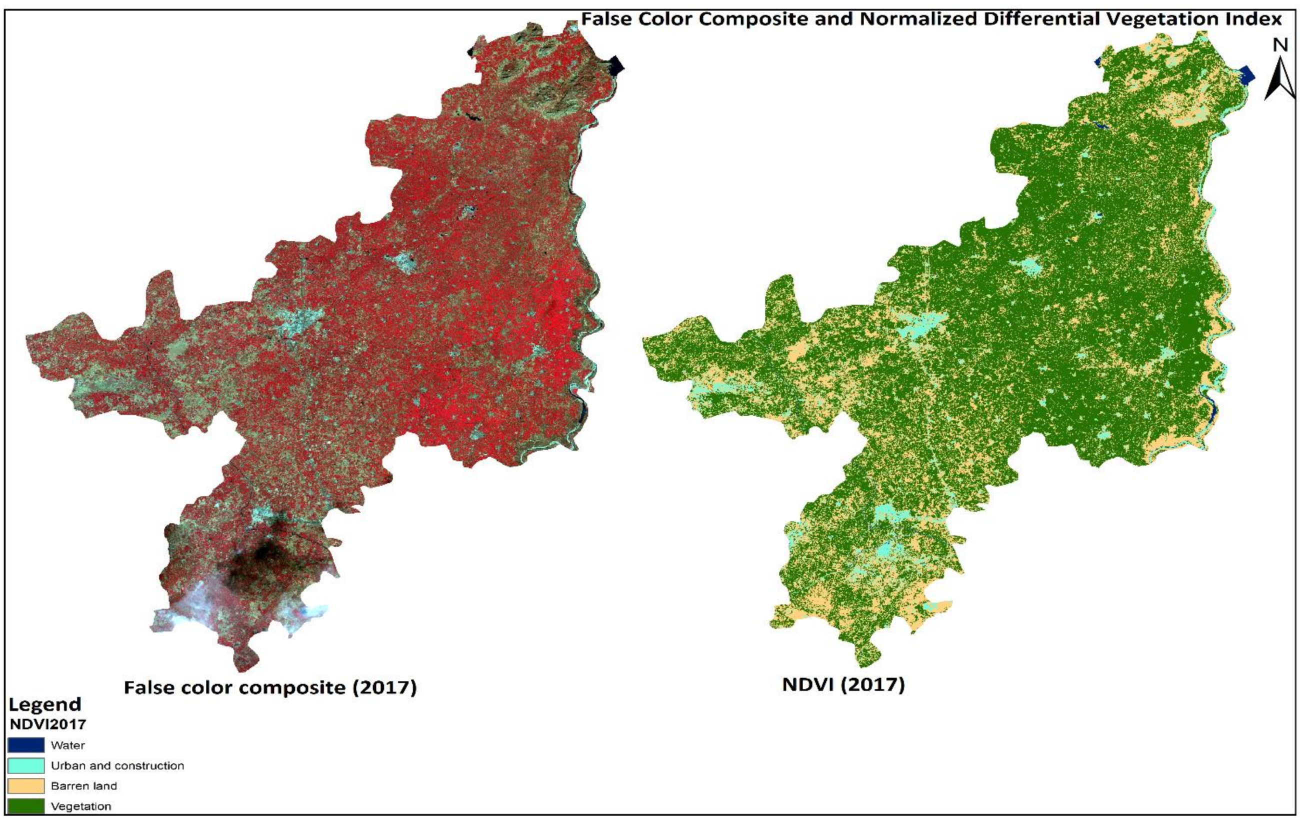

Figure 4: NDVI and FCC of year 2017

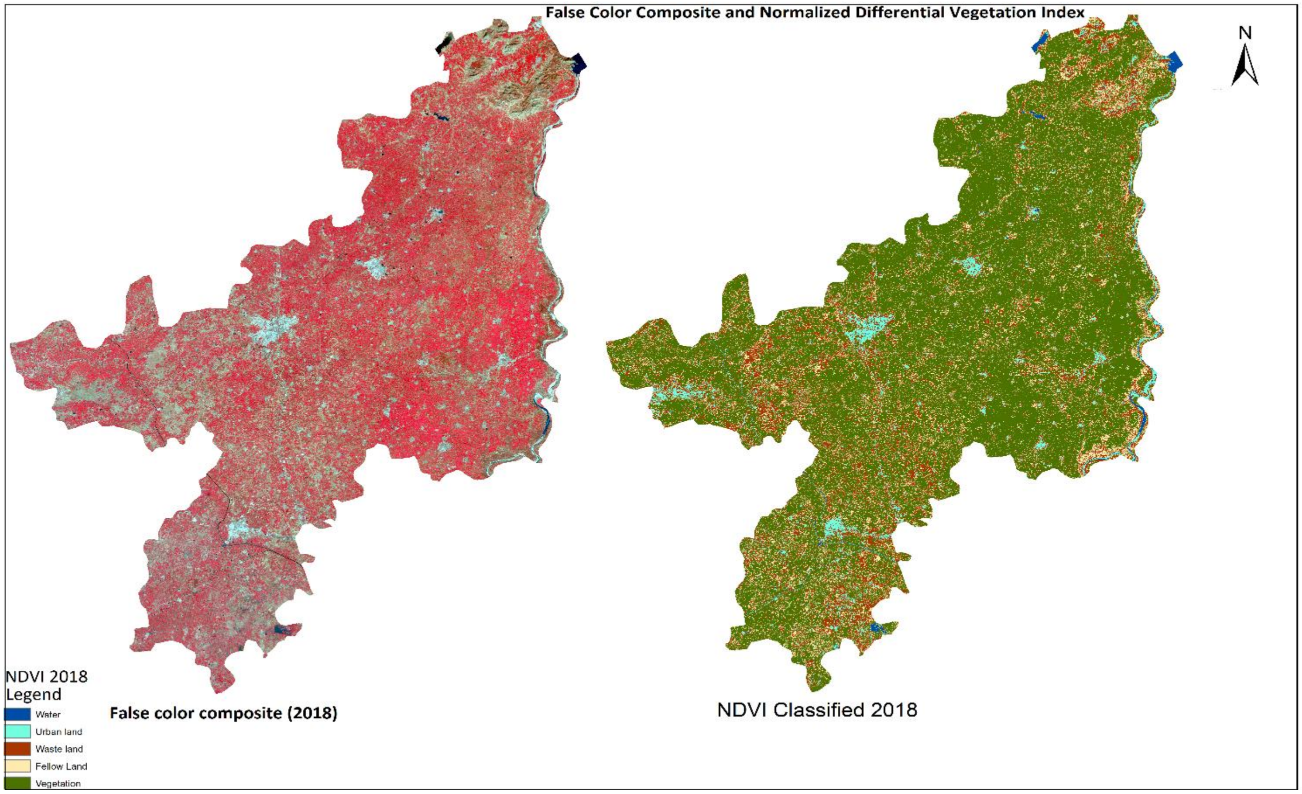

Figure 5: NDVI and FCC of year 2018

Figure:6 2018 NDVI zoomed classified Image

Standardized Precipitation Index (SPI):

Drought risk has been identified using in Mehsana district (Gujarat) by interpolating SPI values over 16 years. SPI values for the years 2002, 2006 and 2017 for Mehsana district were computed per station. From 2002 to 2017 each year SPI values were computed. The SPI values and different classes of wetness and dryness conditions are given in Table below. SPI is computed with help of 4 station daily rainfall data.

The drought that happened in year of 2002 and 2012 was very severe rather than 2017 as explained by the SPI values.Analysis of SPI indicates that SPI was low in drought years as compared to normal monsoon seasons. During drought period, SPI values were negative indicating below normal rainfall resulting in drought condition. However, during the normal monsoon season SPI values were positive.

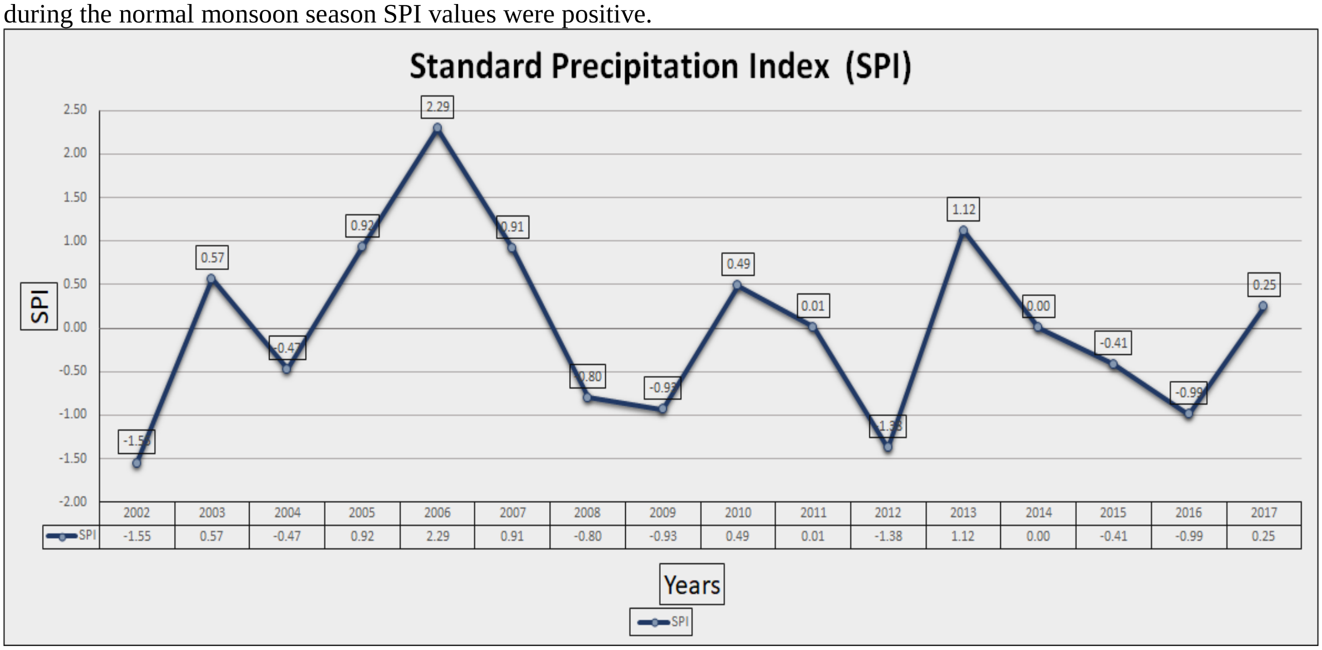

Figure 7: Standard precepitation Index every year

Years	Station Name	SPI	Condition
2002	Ambaliyasan	-1.41329	Severely dry
	Ransipur	-1.76461	Severely dry
	Thol	-1.47317	Moderately dry
2006	Ambaliyasan	0.930178	Near Normal
	Ransipur	3.157814	Extremely wet
	Red Laxmi	3.692767	Extremely wet
	Thol	0.598827	Near Normal
2017	Ambaliyasan	-0.14772	Near Normal
	Ransipur	1.26557	Moderately wet
	Red Laxmi	1.564995	Very wet
	Thol	-1.70073	Severely dry

Figure 8: Selected year per station SPI

Annual SPI:		
Year	**Values**	**Condition**
2002 - 2003	-1.54	Severely Dry
2003 - 2004	0.56	Near Normal
2004 - 2005	-0.47	Near Normal
2005 - 2006	0.92	Near Normal
2006 - 2007	2.29	Extremely Wet
2007 - 2008	0.91	Near Normal
2008 - 2009	-0.80	Near Normal
2009 - 2010	-0.93	Near Normal
2010 - 2011	0.48	Near Normal
2011 - 2012	0.01	Near Normal
2012 - 2013	-1.37	Moderately Dry
2013 - 2014	1.12	Moderately Wet
2014 - 2015	0.00	Near Normal
2015 - 2016	-0.41	Near Normal
2016 - 2017	-0.99	Near Normal
2017 - 2018	0.24	Near Normal

Figure 9: SPI in tabular form

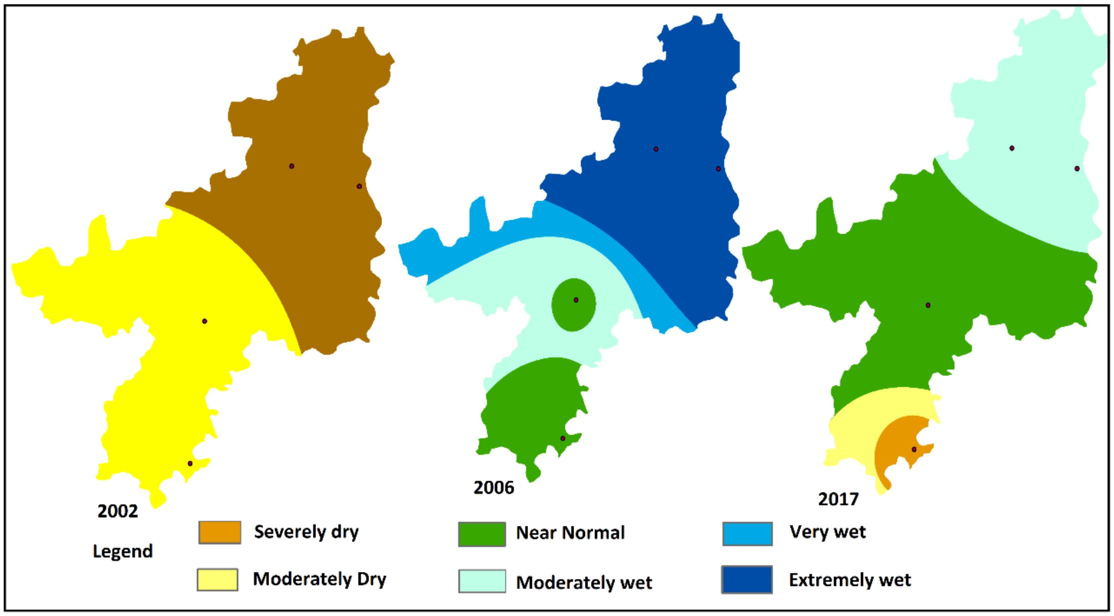

Figure 10: SPI with Inverse Distance Weighted (IDW)

Aridity Index:

A measure of the precipitation effectiveness or aridity of a region, proposed by De Mortonne in 1925. Aridity index values for the drought seasons were below 10 and for normal seasons these values raised from 12 to 25. The higher aridity values indicate semi-arid conditions in Mehsana district. Here Red Laxmi was only available station with temperature year from 2006 to 2017. In the year 2012 the drought was nearly same as 2002 by seeing rainfall values so we can assume that 2012 value and 2002 values can be nearly similar.

Years	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Aridity	35.18	25.95	13.48	12.27	21.58	19.26	9.66	27.25	18.75	15.76	11.89	20.33
Condition	Humid	Sub Humid	Arid	Arid	Normal	Arid	Semi Arid	Sub humid	Arid	Arid	Arid	Normal

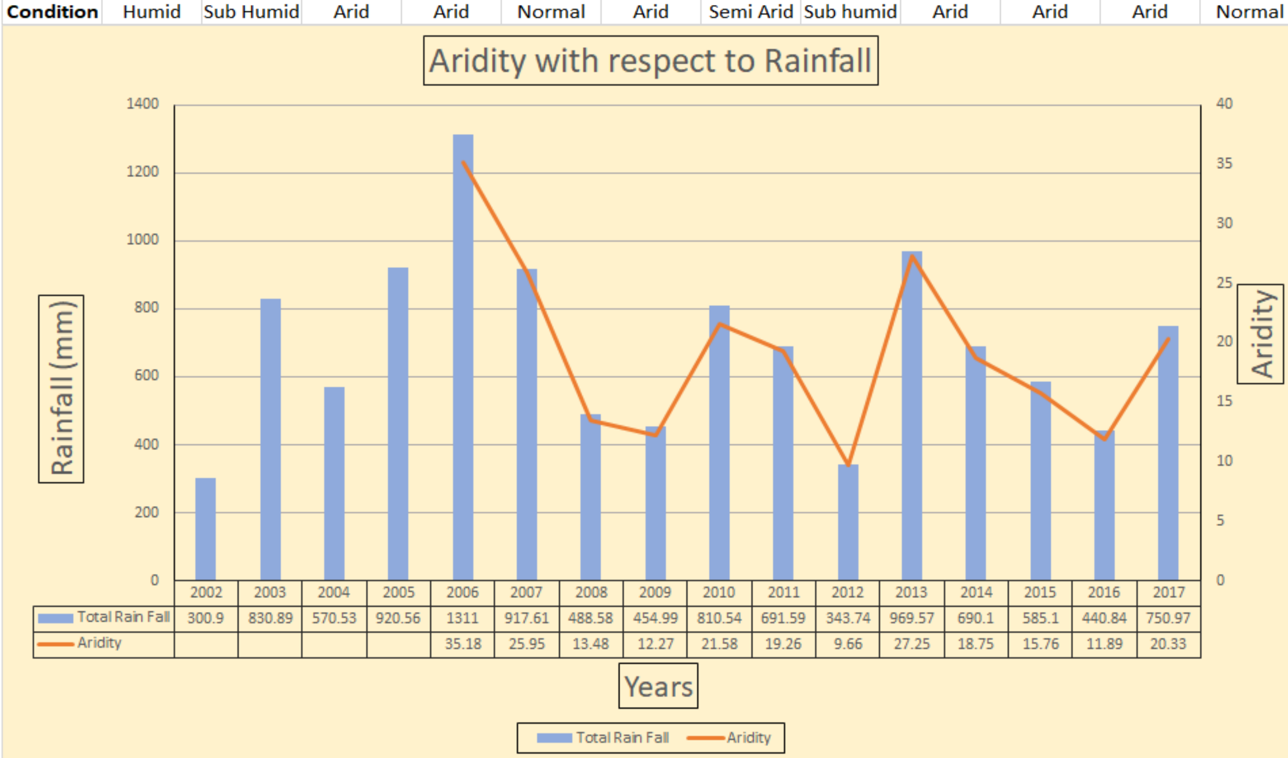

Figure 11: Aridity Index with compared to rainfall

Land Use Change Analysis:
Supervised classification of Landsat data of 2002 and 2018 was carried out using maximum likelihood supervised classification technique. Area under agriculture and other vegetation classes was computed and changes in different classes during last sixteen years (from 2002 to 2018) was computed. now the result indicated that agriculture area has increased by 3% during 2018 as compared to 2002.this classification was done in ArcGIS.

OID	Value	Count	Area	Area_per
0	1	64253	57.8277	1.3147
1	2	2482012	2233.81	50.7851
2	3	8825	7.9425	0.180571
3	4	2594	2.3346	0.053076
4	5	2329604	2096.64	47.6666

Figure 12: 2002 classification (value 1-Urban, 2-shallow water, 3- deep water, 4-barren land 5-Vegetation)

OID	Value	Count	Area	percentage
0	1	268732	241.859	5.51057
1	2	17165	15.4485	0.351982
2	3	4085	3.6765	0.083766
3	4	2124692	1912.22	43.5684
4	5	2462004	2215.8	50.4853

Figure 13: 2018 classification (value 1-Urban, 2-Barren land, 3- deep water, 4-Shallow water 5-Vegetation)

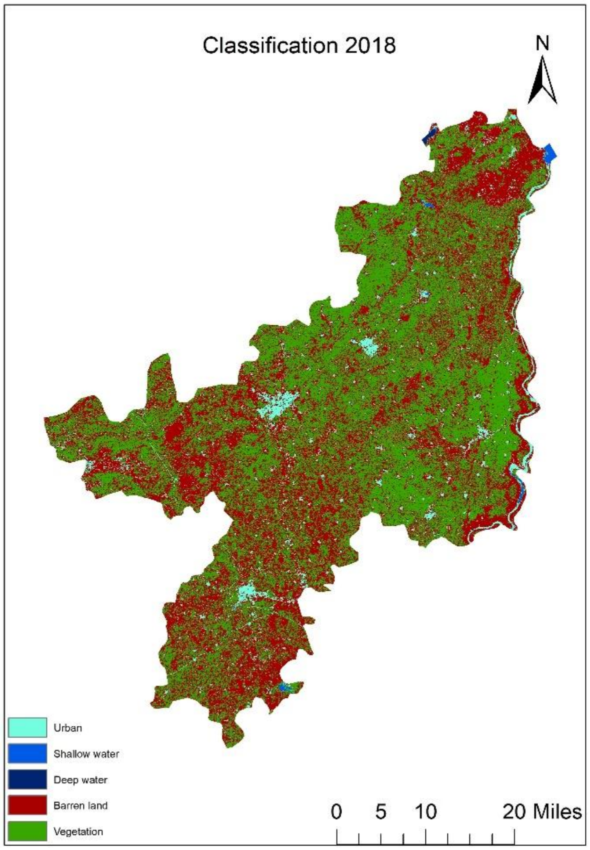

Figure 14: Maxlikelihood Supervised classification 2018

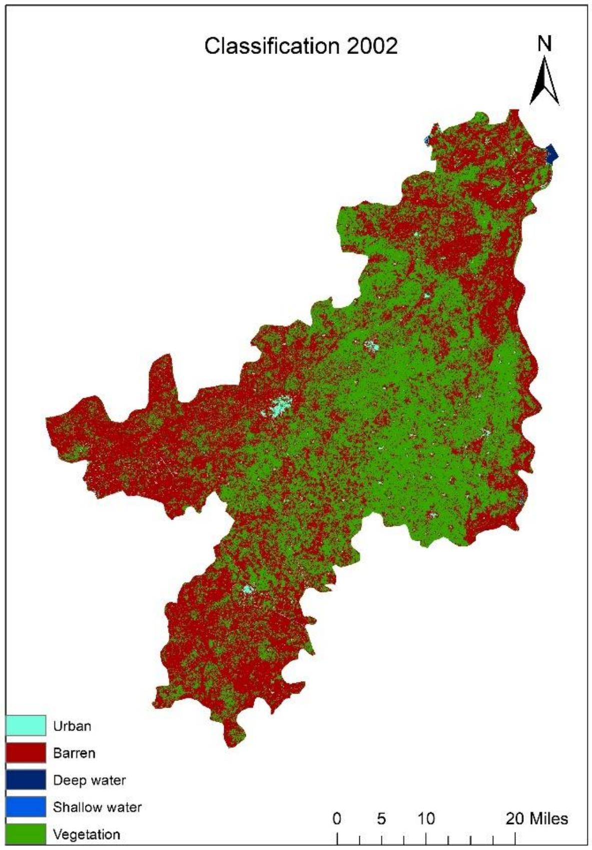

Figure 15: Maxlikelihood Supervised classification 2002

Accuracy assessment and Confusion matrix:

A confusion matrix is a table that is often used to describe the performance of a classification model (or "classifier") on a set of test data for which the true values are known. Two-year images have been set to check the output accuracy. Kappa coefficients are found to find out the accuracy. The accuracy of year 2002 and 2018 is 94% and 91% respectively and kappa values are 0.91 and 0.87 respectively.

OID	ClassValue	C_1	C_2	C_3	C_4	C_5	Total	U_Accuracy	Kappa
0	C_1	6	4	0	0	0	10	0.6	0
1	C_2	0	51	0	0	0	51	1	0
2	C_3	0	1	8	1	0	10	0.8	0
3	C_4	0	1	0	9	0	10	0.9	0
4	C_5	0	0	0	0	48	48	1	0
5	Total	6	57	8	10	48	129	0	0
6	P_Accuracy	1	0.894737	1	0.9	1	0	0.945736	0
7	Kappa	0	0	0	0	0	0	0	0.919303

Figure 16: year 2002 Landsat 7 Confusion matrix(Class 1-Urban, 2-shallow water, 3- deep water, 4-barren land 5-Vegetation)

OID	ClassValue	C_1	C_2	C_3	C_4	C_5	Total	U_Accuracy	Kappa
0	C_1	6	0	1	3	0	10	0.6	0
1	C_2	0	10	0	0	0	10	1	0
2	C_3	0	0	10	0	0	10	1	0
3	C_4	0	0	0	37	7	44	0.840909	0
4	C_5	0	0	0	0	50	50	1	0
5	Total	6	10	11	40	57	124	0	0
6	P_Accuracy	1	1	0.909091	0.925	0.877193	0	0.91129	0
7	Kappa	0	0	0	0	0	0	0	0.870046

Figure 17: year 2018 Landsat 8 Confusion matrix(Class 1-Urban, 2-Barren land, 3- deep water, 4-Shallow water 5-Vegetation)

V. CONCLUSION

This study was conducted to understand the impact of drought on agriculture in Mehsana district. Landsat digital of 2002 and 2018 covering Mehsana district was analysed using open source qgis software and ArcGIS software. The meteorological data like monthly total rainfall, minimum and maximum temperature, from 2002 to 2017 was analysed to derive aridity index and Standard Precipitation Index (SPI) which are the some of the best indicators of drought conditions. The results indicate that the total agriculture area has increased (47% to 51% from 2002-2018) mainly because of the better rainfall conditions as compare to 2002. 2002 was a drought year in Gujarat state. The aridity index and Standard Precipitation Index (SPI) also indicated that the high rainfall conditions. Aridity index was high and during low rainfall condition aridity was low. During 2016-17 rainfall was not normal and it was below normal therefore during this year as per the aridity index it was semi-arid condition in this district. The Standard Precipitation Index (SPI) also showed that it was positive values when rainfall was very high and had negative values during the below average rainfall conditions. The remote sensing data along with drought indices like aridity and Standard Precipitation Index (SPI) were very useful to understand the drought condition as well as the below normal rainfall conditions.

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